



Faculty of Manufacturing Engineering

**MECHANICAL, PHYSICAL AND MORPHOLOGICAL PROPERTIES
OF KENAF FIBER AND NATURAL FILLER REINFORCED
POLYPROPYLENE HYBRID COMPOSITES**

Mohd Abrar bin Abd Latif

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KENAF FIBER AND NATURAL FILLER REINFORCED POLYPROPYLENE
HYBRID COMPOSITES**

MOHD ABRAR BIN ABD LATIF

**A thesis submitted
in fulfillment of the requirements for the degree of Master of Science in
Manufacturing Engineering**

Faculty of Manufacturing Engineering

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2017

DECLARATION

I declare that this thesis entitled “Mechanical, Physical and Morphological Properties of Kenaf Fiber and Natural Filler Reinforced Polypropylene Hybrid Composites” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MOHD ABRAR BIN ABD LATIF

Date :

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Science in Manufacturing Engineering.

Signature :

Supervisor Name : DR. MOHD EDEEROZEY BIN ABD MANAF

Date :

Signature :

Co-Supervisor Name : DR. ZURINA BINTI SHAMSUDIN

Date :

ABSTRACT

Natural fibers have become the potential alternatives to replace synthetic fibers due to its low cost, renewable, biodegradable, environmentally friendly and comparable mechanical properties to the synthetic fibers. Although many researches had been carried out on the natural fibers reinforced polymer composites, there are still not many studies reported on hybrid composites that use a combination of bio-based fibers and particles as reinforcements. In this study, the effects of type and heat treatment of the natural filler, as well as the kenaf fiber form, on the properties of kenaf/polypropylene (kenaf/PP) composite were evaluated using mechanical, physical and morphological analysis. The composites were fabricated using melt mixing, extrusion and compression moulding processes. As the results, firstly, it was found that the kenaf short fiber/PP composite added with rubber seed shell powder (RSSP) exhibits higher overall mechanical properties compared to the oil palm shell powder (OPSP) added composite. This is probably due to higher cellulose content in RSSP that can create good intermolecular and intramolecular hydrogen bonds, thus improve the mechanical properties. However, the higher cellulose content of the RSSP leads to higher water absorption of the RSSP added composite. Secondly, the kenaf non woven/OPSP/PP demonstrates higher mechanical properties compared to the kenaf short fiber/OPSP/PP hybrid composites, uniform fiber architecture and orientation of kenaf non woven, which produces higher mechanical properties compared to short fibers that are randomly distributed in the composite. Nevertheless, the kenaf non woven/OPSP/PP exhibits higher water absorption and thickness swelling because of the continuous nature of the fibers in non woven sheet as opposed to the isolated fibers surrounded by hydrophobic polymer matrix in the short fiber composite. Thirdly, the kenaf non woven/PP added with activated carbon of oil palm shell powder (ACOPSP) shows the highest increment in mechanical properties, followed by the activated carbon of oil palm shell in granule form (ACOPS), without affecting their density. This is due to higher surface areas exhibited by the ACOPSP and ACOPS compared to the untreated OPSP. The high surface area of the activated carbons particles can enhance the interfacial bonding of the fiber-matrix, and consequently improves the mechanical properties of the composites. However, the kenaf non woven/PP added with activated carbon of OPSP experiences higher water absorption and thickness swelling, than the composite added with untreated OPSP due to the higher surface area and porous structure in the activated carbon of OPSP. Kenaf fiber/natural fillers reinforced PP composites have the potential to be applied in various areas, particularly in automotive industry due to their low density. The composites can be considered in the manufacturing of interior car parts such as dashboard, panels at car doors, parcel shelves, seatbacks, spare tyre covers and pans.

ABSTRAK

Gentian semulajadi berpotensi menggantikan gentian sintetik kerana kosnya yang rendah, boleh diperbaharui, boleh terbiodegradasi, mesra alam dan mempunyai ciri-ciri mekanikal yang boleh menyaingi ciri-ciri yang terdapat pada gentian sintetik. Kajian tentang gentian semulajadi sebagai penetulang komposit polimer telah banyak dijalankan, tetapi, komposit hibrid terutamanya yang menggunakan gabungan antara gentian semulajadi dan partikel sebagai penetulang komposit masih lagi belum dikaji secara meluas. Dalam kajian ini, kesan-kesan jenis dan rawatan haba pada pengisi semulajadi, serta bentuk gentian kenaf terhadap komposit kenaf/polipropilena (kenaf/PP), telah dianalisis berdasarkan ciri-ciri mekanikal, fizikal dan morfologikal komposit tersebut. Komposit-komposit telah difabrikasi menerusi proses pencampuran lebur, penyemperitan dan pengacuan mampatan. Keputusannya, komposit kenaf/PP yang ditambah dengan serbuk cengkerang biji getah (RSSP) telah menghasilkan ciri-ciri mekanikal yang tinggi secara keseluruhan berbanding komposit yang ditambah dengan serbuk cengkerang kelapa sawit (OPSP) kerana RSSP mengandungi kuantiti selulosa yang tinggi lantaran menghasilkan ikatan hidrogen intermolekular dan hidrogen intramolekular, seterusnya menghasilkan ciri-ciri mekanikal yang tinggi. Kandungan selulosa yang tinggi menyebabkan penyerapan air yang tinggi bagi komposit RSSP berbanding komposit OPSP. Kedua, komposit hibrid kenaf bukan tenunan/OPSP/PP telah menunjukkan ciri-ciri mekanikal yang tinggi berbanding komposit hibrid kenaf gentian pendek/OPSP/PP kerana kenaf bukan tenunan mempunyai bentuk gentian yang sekata, berbanding kenaf gentian pendek yang bertaburan secara rawak di dalam komposit. Kenaf bukan tenunan/OPSP/PP menghasilkan kadar penyerapan air dan perubahan ketebalan yang lebih tinggi berbanding kenaf gentian pendek/OPSP/PP kerana kepingan bukan tenunan mempunyai bentuk gentian yang bersambung secara semulajadi, berbanding dengan gentian yang terpisah, yang dikelilingi oleh matrik polimer yang hidrofobik di dalam komposit gentian pendek. Ketiga, komposit kenaf bukan tenunan/PP yang ditambah dengan karbon teraktif serbuk cengkerang kelapa sawit (ACOPSP) menghasilkan ciri-ciri mekanikal yang paling tinggi, diikuti oleh komposit karbon teraktif dalam bentuk biji (ACOPS), tanpa menjejaskan ketumpatan komposit tersebut. Hal ini kerana ACOPSP dan ACOPS mempunyai luas permukaan yang lebih tinggi berbanding OPSP yang tidak dirawat dengan rawatan haba. Oleh itu, partikel ACOPSP boleh meningkatkan ikatan antaramuka diantara gentian dan matrik sekaligus meningkatkan ciri-ciri mekanikal komposit tersebut. Komposit kenaf/PP yang ditambah dengan karbon teraktif OPSP menghasilkan kadar penyerapan air dan perubahan ketebalan yang tinggi berbanding komposit OPSP disebabkan oleh ACOPSP mempunyai luas permukaan yang tinggi, serta permukaannya yang lebih berliang berbanding OPSP. Komposit hibrid PP dengan kenaf/pengisi semulajadi sebagai penetulang boleh diaplikasikan dalam pelbagai produk, terutamanya dalam industri automotif untuk mengambil manfaat dari sifat ringannya. Komposit ini boleh diaplikasikan dalam pembuatan komponen dalaman kereta seperti papan pemuka, panel pada pintu kereta, rak, tempat duduk, penutup dan bekas tayar simpanan.

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LIST OF ABBREVIATIONS

AA	-	Acrylic acid
ACOPS	-	Granule activated carbon of oil palm shell
ACOPSP	-	Activated carbon of oil palm shell powder
AIV	-	Aggregate impact value
ASTM	-	American Society for Testing and Materials
CPE	-	Chlorinated polyethylene
ECER	-	East Coast Economic Region
EFB	-	Empty fruit bunch
EGMA	-	Ethylene glycidyl methacrylate
EPDM	-	Ethylene propylene-diene copolymer
EPM	-	Ethylene-propylene copolymer
EPR-g-MA	-	Maleic anhydride grafted ethylene propylene rubber
EPR	-	Ethylene-propylene elastomers
EU	-	European Union
EVA	-	Ethylene-vinyl acetate
GDP	-	Gross Domestic Product
GPa	-	Gigapascal
GMA	-	Glycidyl methacrylate
HDPE	-	High density polyethylene
L/D	-	Length to diameter

LDPE	-	Low density polyethylene
LGM	-	Lembaga Getah Malaysia
LKTN	-	Lembaga Kenaf dan Tembakau Negara
MA	-	Maleic anhydride
MAGPP	-	Maleic anhydride grafted polypropylene
MARDI	-	Malaysian Agricultural Research and Development Institute
MBS	-	Methyl methacrylate-butadiene-styrene copolymer
MFI	-	Melt Flow Index
MPa	-	Megapascal
MPOC	-	Malaysian Palm Oil Council
MREPC	-	Malaysian Rubber Export Promotion Council
OPA	-	Oil palm ash
OPF	-	Oil palm frond
OPKS	-	Oil palm kernel shell
OPS	-	Oil palm shell
OPSP	-	Oil palm shell powder
OPT	-	Oil palm trunk
PE-g-MA	-	Maleic anhydride grafted polyethylene
PLA	-	Polylactic acid
PMC	-	Polymer Matrix Composite
POME	-	Palm oil mill effluent
PP-g-AA	-	Acrylic acid grafted polypropylene
PS	-	Polystyrene
PVC	-	Poly vinyl chloride
RISDA	-	Rubber Industry Smallholders Development Authority

RLDPE	-	Recycled low density polyethylene
RMK-7	-	Seventh Malaysia Plan
RMK-8	-	Eighth Malaysia Plan
RMK-9	-	Ninth Malaysia Plan
RSS	-	Rubber seed shell
RSSF	-	Rubber seed shell flour
RSSP	-	Rubber seed shell powder
SEBS-g-MA	-	Maleic anhydride grafted styrene-ethylene/butylenes-styrene
SEM	-	Scanning Electron Microscope
SIS	-	Styrene-isoprene-styrene
SMA	-	Styrene maleic anhydride
SSA	-	Specific surface area
TEM	-	Transmission Electron Microscope
TS	-	Thickness Swelling
UTM	-	Universal Testing Machine
UV	-	Ultra violet
w/w	-	Mass fraction
WA	-	Water Absorption

LIST OF SYMBOLS

$^{\circ}\text{C}$	-	Celsius
σ_f	-	Flexural stress
ϵ_f	-	Flexural strain
μm	-	Micrometer
3D	-	Three dimensional
CO_2	-	Carbon dioxide
cm	-	Centimeter
cm^3	-	Centimeter cube
EB	-	Modulus of elasticity in bending
g/10 min		Gram per 10 minutes
g/cm ³		Gram per cubic centimeter
Hz	-	Hertz
kg	-	Kilogram
kg/m ³		kilogram per cubic meter
kJ/m	-	Kilojoule per meter
m	-	Meter
m ² /g		Meter square per gram
mm	-	Milimeter
N	-	Newton
N ₂	-	Nitrogen

N/mm	-	Newton per milimeter
phc	-	Per hundred compound
rpm	-	Revolution per minutes
V	-	Volt
W	-	Watt
wt%	-	Weight percentage

LIST OF PUBLICATIONS

Abrar, A.L.M., Edeerozey, A.M.M., and Zurina, S., 2016. Mechanical Properties of Kenaf Reinforced Polypropylene Composites Added with Oil Palm Shell Powder and Its Activated Carbon. In: *Proceeding of Innovative Research and Industrial Dialogue*, Melaka, Malaysia, 20 December 2016. (Will be indexed in ISI Thompson Conference)

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Petroleum-derived materials can be considered as non-renewable materials as petroleum takes thousands of years to be produced naturally. Therefore, many researches have been carried out in the hope to discover alternative materials that are more environmentally friendly and sustainable in order to replace petroleum-based materials. Natural fiber is a sustainable material that can potentially replace conventional glass and carbon fiber as reinforcement material in composite industry. Realizing this, attention has shifted towards the development and characterization of natural fiber reinforced materials for various purposes. Even high-tech industries such as constructions, automotive, aerospace and packaging industries have shown an interest in using more natural fiber reinforced composites (Saba et. al., 2014). For example, in automotive industry, natural fiber reinforced plastic composite can be developed as a potential material to decrease the vehicle weight, thus improve fuel efficiency. Natural fibers such as jute, hemp and kenaf are not only renewable and degradable, but they also offer other advantages such as low density, high toughness, comparable specific strength, reduction in tool wear and less production of energy, which make them eligible to replace synthetic fiber (Ku et al., 2011).

Besides reducing the dependence on non-renewable resources such as petrochemicals, natural fibers can also be used in combination with various thermoplastics to produce bio-based polymer composite products that are recyclable, thus lessen the impact on the environments. The combination of eco-friendly and recyclability generate a

significant approach to improve the sustainability of the polymeric materials (Kam and Ahmad, 2015).

Kenaf is an important source of plant fiber. It has been planted in Malaysia commercially since early 2000. The Malaysian government has suggested kenaf to replace tobacco as industrial crop due to its lower price and import duties compared to tobacco. Since then, Malaysian Agricultural Research and Development Institute (MARDI) has done many researches on agronomic practices for kenaf cultivation including mechanization, extraction and processing of kenaf fiber as well as on applications for instance as bio-composite and animal feeding (Edeerozey et al., 2007).

Recently, kenaf fiber reinforced thermoplastic has produced an increasing interest in making low cost engineering materials due to its potential as environmentally friendly and cost-effective materials. Since kenaf fiber exhibits high mechanical properties, low abrasiveness, low density and low cost, it is known to reinforce both thermoplastic and thermosets resins effectively. It shows the possibility of new material to be reinforced with polymer matrix composites. Researchers demonstrated that kenaf layers, kenaf weight fraction and heating time that fabricated by hot pressing could influence the performance of kenaf and polypropylene composite especially in flexural properties (Shibata et al., 2006). Besides that, in another study, it is shown that increasing fiber weight fraction in kenaf/polypropylene composite will increase ultimate strength, tensile modulus, and impact strength of the composite (Popa et al., 2013).

Natural fibers are available in short and long fiber. The short or discontinuous fiber possesses a random orientation and distribution in a composite. Furthermore, continuous or long fiber can be divided into woven and non woven forms. The non woven and woven fiber form can produce unidirectional and bidirectional reinforcement in a composite (Agarwal et al., 1990)